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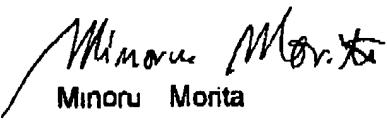
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[Title of the Invention]   Manetoresistance Effect Head and Manufacturing Method Thereof, and Recording/Reproducing Magnetoresistance Effect Head and Manufacturing Method Thereof

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[Title of the Invention]   MAGNETORESISTANCE EFFECT HEAD, MANUFACTURING

METHOD THEREOF, AND MAGNETIC RECORDING/REPRODUCING

MAGNETORESIDSTANCE EFFECT HEAD AND MANUFACTURING METHOD THEREOF

[What is claimed is]

1.   A magnetoresistance effect head, comprising:

a magnetoresistance effect element formed on a main surface of a substrate;

a laminate film disposed adjacent to the magnetoresistance effect element , the laminate film

being composed of an amorphous layer, a metal crystal layer, and a hard magnetic film

containing Co as a structural element which are successively laminated on the main surface

of the substrate, the amorphous layer and the metal crystal layer having a thickness of 500

angstrom or less; and

a pair of lead terminals which are connected to both edges of the magnetoresistance effect

element.

2.   A magnetoresistance effect head, comprising:

a gap layer formed on a main surface of a substrate;

a magnetoresistance effect element formed on a surface of the gap layer;

a laminate film disposed adjacent to the magnetoresistance effect element, the laminate film

being composed of an amorphous layer, a metal crystal layer and a hard magnetic film

containing Co as a structural element which are successively laminated on the surface of the

gap layer; and

a pair of lead terminals which are connected to both edges of the magnetoresistance effect

element.

3.   A magnetoresistance effect head, comprising:

a magnetoresistance effect element formed on a main surface of a substrate;

a hard magnetic film formed on the main surface of the substrate and disposed adjacent to

the magnetoresistance effect film, the hard magnetic film having a bi-crystal structure; and

a pair of lead terminals which are connected to both edges of the magnetoresistance effect

1

element.

4. The magnetoresistance effect head according to claim 3, wherein a laminate film as an under layer of the hard magnetic film is disposed on the substrate, the laminate film being composed of an amorphous layer and a metal crystal layer which are successively laminated from a substrate side.

5. The magnetoresistance effect head according to any one of claims 1, 2 and 4, wherein the amorphous layer is a magnetic layer and the metal crystal layer is a magnetic layer.

6. The magnetoresistance effect head according to any one of claims 1, 2 and 4, wherein the amorphous layer and the metal crystal layer contain the same structural element.

7. The magnetoresistance effect head according to claim 2, wherein the amorphous layer is a reaction layer with the gap layer.

8. The magnetoresistance effect head according to claim 1 or claim 4, wherein the amorphous layer is a reaction layer with the substrate.

9. The magnetoresistance effect head according to any one of claims 1, 2 and 4, wherein both the metal crystal layer and the amorphous layer contain at least one element selected from the group consisting of Cr, Ti, Ta, V, W, Zr, Nb, Hf, Mo, and Al.

10 The magnetoresistance effect head according to any one of claims 1, 2 and 4, wherein an average crystal grain diameter of the metal crystal layer is five times or more a thickness of the metal crystal layer.

11. The magnetoresistance effect head according to claim 4, wherein the hard magnetic layer has a bi-crystal structure.

12 The magnetoresistance effect head according to any one of claims 1, 2 and 4, wherein whole thickness of the amorphous layer and the metal crystal layer is 500 angstrom or less.

13 The magnetoresistance effect head according to any one of claims 1, 2 and 4, wherein the metal crystal layer is a reaction layer with the amorphous layer, the metal crystal layer being composed of a reactive crystal layer having a thickness of 80 angstrom or less and a crystal layer formed on a surface of the reactive crystal layer.

14 The magnetoresistance effect head according to any one of claims 1, 2 and 3, wherein the hard magnetic film has a main grain whose crystal grain diameter 500 angstrom or more.

15. The magnetoresistance effect head according to any one of claims 1, 2 and 3, wherein the magnetoresistance effect element is a film exhibiting an isotropic magnetoresistance effect.

16. The magnetoresistance effect head according to any one of claims 1, 2 and 3, wherein the magnetoresistance effect element is a magnetoresistance effect film in which a first magnetic layer, a non-magnetic layer and a second magnetic layer are laminated.

17. The magnetoresistance effect head according to claim 16, wherein the first magnetic layer is extended on a surface of the hard magnetic film, the first magnetic layer being exchange-coupling with the hard magnetic film.

18. The magnetoresistance effect head according to any one of claims 1, 2 and 3, wherein the hard magnetic film is adjacent to both edge portions of the magnetoresistance effect element.

19. A recording/reproducing integration type magnetic head, comprising:

a recording portion comprising a pair of magnetic pole layers which hold a magnetic gap formed on a plane facing a medium therebetween, and a coil which produces a reversal of magnetization of the pair of magnetic poles; and

a reproducing portion comprising the magnetoresistance effect head according to any one of claims 1, 2 and 3.

20. A method of manufacturing of a magnetoresistance effect head, comprising the steps of.

forming an amorphous layer on a main surface of a substrate and a metal crystal layer on the amorphous layer in turn, the whole thickness of the amorphous layer and the metal crystal layer being 500 angstrom or less;

forming a hard magnetic film containing Co as a structural element on a surface of the metal crystal layer;

forming a magnetoresistance effect element adjacent to the hard magnetic film on the main surface of the substrate;

forming a pair of lead terminals which connect with both edges of the magnetoresistance effect element.

21. A method of manufacturing of a magnetoresistance effect head, comprising the steps of:

forming a gap layer on a main surface of a substrate;

forming an amorphous layer on the gap layer, and a metal crystal layer on the amorphous layer;

forming a hard magnetic film containing Co as a structural element on a surface of the metal crystal layer;

forming a magnetoresistance effect element adjacent to the hard magnetic film on a surface of the gap layer; and

forming a pair of lead terminals which connect with both edges of the magnetoresistance effect element

22 A method of manufacturing of a magnetoresistance effect head, comprising the steps of:

forming a hard magnetic film having a bi-crystal structure on a main surface of a substrate;

forming a magnetoresistance effect element adjacent to the hard magnetic film on the main surface of the substrate; and

forming a pair of lead terminals which connect with both edges of the magnetoresistance effect element.

23. The method of manufacturing of a recording/reproducing integrated type magnetoresistance effct head, comprising the steps of:

forming a magnetoresistance effect head of a reproducing portion according to the manufacturing method of any one of claims 20, 21 and 22;

forming a pair of magnetic pole layers which hold a magnetic gap formed on a plane facing a medium therebetween, and

forming a recording portion having a coil which produces a reversal of magnetization of the pair of magnetic poles.

[Description of Detailed Invention]

[0001]

[Technical Field of the Invention]

The invention relates to a magnetoresistance effect head, a manufacturing method thereof and a magnetic recording/reproducing head and a manufacturing method thereof

[0002]

[Prior Art]

Recently, a magnetoresistance effect head which reproduces an information memorized in a magnetic recording medium is studied. The magnetoresistance effect head reproduces the information in the magnetic recording medium by using an MR element which changes its electrical resistance depending on the strength of external magnetic field, and by using the changes of resistance of the MR element.

[0003]

Fig. 36 is a sectional view showing an example of conventional magnetoresistance effect head. In this conventional example, a magnetic sensing layer whose magnetization is reversed depending on an external magnetic field applied to the MR element 6 has an abutted junction type, in which magnetic domains is controlled by a vertical bias of hard magnetic films 5 disposed on both sides of the magnetic sensible layer.

[0004]

A substrate-protection film 2 is formed on a Al_2O_3-TiC substrate 1, and a lower shield film 3 is formed on the substrate- protection film 2 A reproduction portion 12 comprises a gap layer 4 formed on the lower shield film 3, and an MR element 6 including GMR film formed on the surface of the gap layer 4, and is formed as a magnetic domain controlled film at a side of an MR element 6. For example, the reproduction portion 12 comprises a Co based hard magnetic film 5, a pair of lead terminals 7 connected to both edges of the MR element 6 for reading out a variety of magnetic resistance of the MR element, an upper gap film 8 formed on the MR element 6, and an upper shield layer 9 formed on the upper gap film 8. The upper shield layer 9 is simultaneously used as a lower magnetic core of a recording portion 13. A writing portion comprises a magnetic gap film 10 formed on the lower magnetic core, and an

upper magnetic core 11 formed in a partial region on a surface thereof.

As an MR element, an MR film or GMR film is known. As one example, a spin valve structure comprising a ferromagnetic film, non-magnetic film, a ferromagnetic film and an anti-ferromagnetic film which are laminated in turn, is known (Phys. Rev B. , Vol 45806, (19929) (J. Appl. Phys. Vol. 69, 4774(1991)). In this structure, one of two ferromagnetic films which are laminated through a nonmagnetic film is a fixed layer which is fixed and magnetized by an exchange bias due to antiferromagnetic film , another ferromagnetic film which is a sensing layer forms an anti-parallel state with the fixed layer by reversing its magnetization due to an external magnetic field., thus, the change of magnetic resistance being realized.

When the magnetization reversal takes place in the magnetic sensing layer, the occurrence of Barkhausen noise is known. Fig. 37(a) shows a mechanism of the occurrence of Barkhausen noise. When an external magnetic field is applied to a magnetic film 14 which has not controlled magnetic domains and various magnetic domains, the magnetization directions thereof take simultaneously one direction, thereby Barkhausen noise being occurred in the output waves. To the above problem, as shown in Fig. 37(b), it is planed to control the magnetic domains of magnetic film 14 by disposing hard magnetic films on both sides of the magnetic film, so that the magnetic domains in the ferromagnetic film has a single magnetization direction. In order to have a stable single magnetization direction over a long term, it is required to have a stable and high coercive force of magnetic film 14.

On the other hand, as a medium film of a magnetic recording medium, a hard magnetic film is used. By forming a nonmagnetic under film having a thickness of 1000 angstrom or more as under layer of a hard magnetic film, it is planed to increase the crystallinity of the hard magnetic film , to increase the magnetic anisotropy, or to magnetically isolate between crystal grains.

However, since it is structurally difficult to use such a thick film in a magnetoresistance effect head, it could not use the non magnetic under film although there is a problem that Barkhausen noise is occurred due to the low coercive force.

[0005]

6

[Problems to be solve by the Invention]

However, accompanying with the high densification of a magnetic recoding device, it is presumed that a floating height of a magnetoresistance effect head from a magnetic recording medium becomes lower so as to be in a lower floating state, a quasi-contact state or a contact state. Owing to shorten a distance between a head and a medium, a hard magnetic film having a low coercive force easily magnetization-reversed. If the magnetization reversal is occurred, the magnetization of magnetic layer of the MR element would be unstable and the magnetic layer would form magnetic domains to occur Barkhausen noise.

[0006]

As a countermeasure, it is considered to increase a coercive force of a hard magnetic film by forming an under metal film having a thick thickness as an under layer, or to increase a thickness of the hard magnetic film to compensate a bias magnetic field. However, the magnetoresistance effect element carried out such a countermeasure, when a narrower gap is proceeded due to high densification, in the above mentioned abutted junction type, a bias magnetic field leaks to a shield film to decrease an effective bias magnetic field on the magnetic sensing layer, thereby to form a single magnetic domain of the magnetic sensing layer being difficult. Further, when using a hard magnetic film thicker than an MR element, the film thickness center of the hard magnetic film approaches to a fixed layer. Thus, at the interface between the hard magnetic film and antiferromagnetic film which is inferior in its anisotropic magnetic field, the reversal of magnetization of the fixed layer is produced, and the noise is occurred. In addition, when the hard magnetic film is formed on an under layer film to decrease the Barkhausen Noise, in an abutted junction type, the under layer adheres to a side surface of the GMR film 6 previously formed, and results in that a magnetic gap is formed between a magnetic sensing layer of the MR element and the hard magnetic film. This weakens the bias effect on the sensing layer and causes the Barkhausen Noise.

[0007]

On the other hand, in an exchange coupling system of which by extending an MR element to dispose the MR element on a hard magnetic film, the exchange coupling of a ferromagnetic film of the MR element and the hard magnetic film is used, after a thick hard

7

magnetic film is etched by for example an ion milling process, the MR element is formed. Thus, the surface of the gap layer 4 that has been etched becomes rough (uneven). Thus, magnetic characteristics become unstable such that the anisotropic magnetic field Hk becomes unstable, the coercive force Hc takes places in a direction of difficult axis, and the interlayer coupling magnetic field Hin between the magnetic sensible layer and the magnetization fixed layer increases. Such an instability results in Barkhausen noise. The surface roughness of the gap layer 4 also takes place when the surface roughness of the hard magnetic film is transferred by the ion milling process. In addition, as shown in Fig. 38, even if the coercive force Hc (M point) of the hard magnetic film is large, when the residual magnetization Mr is low, the total coercive force Hc (L point) of the GMR film and the hard magnetic film decreases, thereby the occurrence of Barkhausen noise being increased.

[0008]

Furthermore, for improving the magnetic characteristics of magnetoresistance effect element, a new structure of which the hard magnetic film formed on a thin under metal film having a thickness of 500 angstrom or less enables to obtain a stable residual magnetization Mr over a long term is desired.

[0009]

The present invention was made to solve the above problems. An object of the invention is to provide a magnetic recording/reproducing head having a high coercive force, a high saturation magnetization, and an excellent squareness ratio.

[0010]

[Means for solving the problems]

A first aspect of the present invention is a magnetoresistance effect head comprising a magnetoresistance effect element formed on a main surface of a substrate, a laminate film disposed adjacent to the magnetoresistance effect element, the laminate film comprising an amorphous layer, a metal crystal layer, and a hard magnetic film containing Co as a structural element formed on the main surface of the substrate in a sequential order, the amorphous layer and the metal crystal layer having a thickness of 500 angstrom or less; and a pair of lead terminals which are connected to both edges of the magnetoresistance effect

8

element.

[0011]

A second aspect of the present invention is a magnetoresistance effect head comprising a gap layer formed on a main surface of a substrate, a magnetoresistance effect element formed on a surface of the gap layer, a laminate film disposed adjacent to the magnetoresistance effect element, the laminate film comprising an amorphous layer, a metal crystal layer and a hard magnetic film containing Co as a structural element formed on the surface of the gap layer in a sequential order; and a pair of lead terminals which are connected to both edges of the magnetoresistance effect element.

[0012]

A third aspect of the present invention is a magnetoresistance effect head, comprising: a magnetoresistance effect element formed on a main surface of a substrate, a hard magnetic film formed on the main surface of the substrate and disposed adjacent to the magnetoresistance effect film, the hard magnetic film having a bi-crystal structure, and a pair of lead terminals which are connected to both edges of the magnetoresistance effect element.

[0013]

Further, in the magnetoresistance effect head according to claim 3, wherein a laminate film as an under layer of the hard magnetic film is disposed on the substrate, the laminate film comprising an amorphous layer formed on the main surface of the substrate, and a metal crystal layer formed on the amorphous layer in a sequential order from a substrate side.

[0014]

In this connection, in the magnetoresistance effect head according to any one of claims 1 to 3, the amorphous layer mentioned above indicates a solid state in which atoms or molecules do not form a crystal having a regular special arrangement, but they gather.

[0015]

As mentioned above, since the hard magnetic film is formed on the amorphous layer through the metal crystal layer, excellent magnetic characteristics in the coercive force, residual magnetization, saturation magnetization, and squareness ratio can be obtained, as

9

described in detail in the first and second embodiments. Thereby, the present invention can effectively suppress the occurrence of Barkhausen noise.

[0016]

In the present invention, it is preferable that the hard magnetic film has a bi-crystal structure. In the bi-crystal structure, sub-grains are present in each of main grains. As shown in Fig. 5, the crystal orientation directions of the sub-grains in the main grain are perpendicular to each other (80 to 100 degree). Owing to the crystal structure, Thus, since the sub-grains having a high crystal magnetic anisotropy in plane are perpendicular to each other, the hard magnetic film having the bi-crystal structure can have both of high coercive force Hc and high saturation magnetization Mr .

[0017]

In the present invention, the following structures can be given as preferable embodiments.

1) The amorphous layer is a magnetic layer and the metal crystal layer is a magnetic layer.

2) The amorphous layer and the metal crystal layer contain the same structural element.

3) In the second aspect of the invention, the amorphous layer is a reaction layer with the gap layer.

4) In the first and third aspect of the invention, the amorphous layer is a reaction layer with the substrate.

5) In the second aspect of the invention, the gap layer is an alumina layer

6) The metal crystal layer and the amorphous layer both contain at least one element selected from the group consisting of Cr, Ti, Ta, V, W, Zr, Nb, Hf, Mo and Al.

7) An average crystal grain diameter of the metal crystal layer has five times a thickness of the metal crystal layer.

8) The total thickness of the amorphous layer and the metal crystal layer is 500 angstrom or less.

9) The metal crystal layer is a reaction layer with the amorphous layer, and consists of a reactive crystal layer having a film thickness of 80 angstrom or less and a crystal layer being on a surface of the reactive crystal layer.

10

10) A crystal grain diameter of main grains of the hard magnetic film is 500 angstrom or more.

11) A residual magnetization Mr of the hard magnetic film is 650 emu/cc or more.

12) A coercive force Hc of the hard magnetic film is 2000 Oe or more.

13) A squareness ratio of the hard magnetic film is 0.9 or more.

14) The magnetoresistance effect element is a film showing an anisotropic magnetoresistance effect.

15) The magnetoresistance effect element is a magnetoresistance effect film comprising a laminated film of a first magnetic layer, a nonmagnetic layer, and a second magnetic layer.

16) The first magnetic layer is extended on a surface of the hard magnetic layer, and is exchange-coupled with the hard magnetic layer.

17) The hard magnetic layer is adjacent to the both edges of the magnetoresistance effect element.

[0018]

In order to solve the problems mentioned above, the fourth aspect of the invention is to provide a recording/reproducing integrated type magnetoresistance effect head comprising a reproducing portion and a recording portion, the reproducing portion comprising: a magnetoresistance effect element formed on a main surface of a substrate, a laminate film disposed adjacent to the magnetoresistance effect element and comprising an amorphous layer and metal crystal layer having a total layer thickness of 500 angstrom or less, and a hard magnetic film containing Co as a structural element, the amorpjous layer, the metal crystal layer and the hard magnetic being sequentially formed on the main surface of the substrate, a pair of lead terminals disposed to connect both edges of the magnetoresistance effect element, and the recording portion comprising: a pair of magnetic pole layers holding a magnetic gap therebetween, the magnetic gap being formed on a plane facing a medium, and a coil which generates a magnetic reverse of the pair of magnetic layers.

[0019]

In order to solve the problems mentioned above, the fifth aspect of the invention is to

11

provide a recording/reproducing integrated type magnetoresistance effect head comprising a reproducing portion and a recording portion, the reproducing portion comprising: a gap layer formed on a main surface of a substrate, a magnetoresistance effect element formed on a surface of the gap layer, a laminate film disposed adjacent to the magnetoresistance effect element, the laminate film comprising an amorphous layer, a metal crystal layer, and a hard magnetic film containing Co as a structural element which are formed in turn on a surface of the gap layer, a pair of lead terminals connected to both edges of the magnetoresistance effect element, and the recording portion comprising a pair of magnetic pole layers holding therebetween a magnetic gap formed on a surface facing a medium and a coil which generates a magnetic reverse of the pair of magnetic pole layers.

[0020]

The sixth aspect of the invention is to provide a recording/reproducing integrated type magnetoresistance effect head comprising a reproducing portion and a recording portion, the reproducing portion comprising a magnetoresistance effect element formed on a main surface of a substrate, a hard magnetic film disposed adjacent to the magnetoresistance effect element and having a bi-crystal structure, and a pair of lead terminal connected to both edges of the magnetoresistance effect element, and the recording portion comprising a pair of magnetic pole layers holding a magnetic gap therebetween, the magnetic gap being formed on a plane facing a medium, and a coil which generates a magnetic reverse of the pair of the magnetic pole layers.

[0021]

The seventh aspect of the invention is to provide a manufacturing method of a magnetoresistance effect head, comprising the steps of forming an amorphous layer and a metal crystal layer on a main surface of a substrate in turn, the amorphous layer and the metal crystal layer having a thickness of 500 angstrom or less, forming a hard magnetic film containing Co as a structural element on a surface of the metal crystal layer, forming a magnetoresistance effect element adjacent to the hard magnetic film on the main surface of the substrate, and forming a pair of lead terminals connecting to both edges of the magnetoresistance effect element.

12

[0022]

The eighth aspect of the invention is to provide a manufacturing method of a magnetoresistance effect head, comprising the steps of forming a gap layer on a main surface of a substrate, forming an amorphous layer and a metal crystal layer on a surface of the gap layer, forming a hard magnetic film containing Co as a structural element on a surface of the metal crystal layer, forming a magnetoresistance effect element adjacent to the hard magnetic film on the surface of the gap layer, and forming a pair of lead terminals connecting to both edges of the magnetoresistance effect element.

[0023]

The ninth aspect of the invention is to provide a manufacturing method of a magnetoresistance effect head, comprising the steps of forming a hard magnetic film having a b-crystal structure on a main surface of a substrate, forming a magnetoresistance effect element adjacent to the hard magnetic film on the main surface of the substrate, and forming a pair of lead terminals connecting to both edges of the magnetoresistance effect element

[0024]

The tenth aspect of the invention is to provide a manufacturing method of a recording/reproducing integrated type magnetoresistance effect head, comprising the steps of forming an amorphous layer and a metal crystal layer on a main surface of a substrate in turn, the amorphous layer and the metal crystal layer having a thickness of 500 angstrom or less, forming a hard magnetic film containing Co as a structural element on a surface of the metal crystal layer, forming a magnetoresistance effect element adjacent to the hard magnetic film on the main surface of the substrate, forming lead terminals connecting to both edges of the magnetoresistance effect element, forming a pair of magnetic pole layers holding a magnetic gap on a surface facing a medium, and forming a recording portion having a coil which generate a magnetic reverse of the pair of the pair of magnetic pole layers.

[0025]

The eleventh aspect of the invention is to provide a manufacturing method of a recording/reproducing integrated type magnetoresistance effect head, comprising the steps

13

of forming a gap layer on a main surface of a substrate, forming an amorphous layer and a metal crystal layer on surface of the gap layer, forming a hard magnetic film containing Co as a structural element on a surface of the metal crystal layer, forming a magnetoresistance effect element adjacent to the hard magnetic film on the surface of the gap layer, forming a pair of lead terminals connecting to both edges of the magnetoresistance effect element, forming a pair of magnetic pole layers holding a magnetic gap on a plane facing a medium, and recording portion having a coil which generates a magnetic reverse of the pair of the magnetic pole layers.

[0026]

The twelveth aspect of the invention is to provide a manufacturing method of a recording/reproducing integrated type magnetoresistance effect head, comprising the steps of forming a hard magnetic layer having a bi-crystal structure on a main surface of a substrate, forming a magnetoresistance effect element adjacent to the hard magnetic film on a main surface of a substrate, forming a pair of lead terminals connecting to both edges of the magnetoresistance effect element, forming a magnetic pole layers holding a magnetic gap therebetween on a plane facing a medium, and forming a recording portion having a coil which generates a magnetic reverse of the pair of the magnetic pole layers.

[0027]

[Embodiments of the invention]

We will describe the embodiments of the invention by referring the drawings.

[0028]

In the first and second embodiments, we will describe in detail the structure and effect of a hard magnetic film which is used as a longitudinal bias film of a magnetoresistance effect element in the magnetoresistance effect head of the invention. Further, in the third and fourth embodiments, we will describe in detail the structure and effect of the magnetoresistance effect head of the invention, concretely an exchange coupling type magnetoresistance effect head and an abutted junction type magnetoresistance effect head, and the structure .

(First embodiment)

Fig. 1 is a sectional view for explaining an embodiment of the magnetoresistance effect

14

head of the invention.

On a surface of a substrate such as an $Al_2O_3.TiC$ substrate (not shown), a nonmagnetic gap film 21 such as an alumina film 21 was formed with a film thickness of about 1000 angstrom. Further, on the nonmagnetic film 21, a reactive amorphous layer 22 having a thickness of about 20 angstrom and containing Cr, a reactive crystal layer 23 having a thickness of about 20 angstrom and containing Cr, and a crystal layer 24 of Cr and having a thickness of about 40 angstrom were formed. These the reactive amorphous layer 22, the reactive crystal layer 23 and the crystal layer 24 constituted an under film 26 of a hard magnetic film 25 such as a CoPt film 25 and the like

[0029]

A magnetoresistance effect element (not shown) adjacent to the CoPt film 25, and a pair of lead terminals (not shown) connecting to both edges of the magnetoresistance effect element.

[0030]

The reactive amorphous layer 22 and the reactive crystal layer 23 contained a structural element of the nonmagnetic film. In this embodiment, at least one of Al and O was contained, and the Al and/or O is reacted with Cr.

[0031]

Next, we will describe a film-shape of the hard magnetic film of the present embodiment.

[0032]

Figs. 2 and 3 show the sectional Transmission Electron Microscope (TEM) photograph of the embodiment and an inventor's sketch of the sectional TEM photograph, respectively. From the drawings, it is apparent that the under-film 26 containing Cr was constituted of a three layered structure of the crystal layer 24, the reactive crystal layer 23 and the reactive amorphous layer 22.

[0033]

In addition, Figs. 4 and 5 show the plane TEM photograph of the embodiment and an inventor's sketch thereof. An average crystal grain diameter of the CoPt film 25 was relatively

15

large and is in the range of 500 to 1000 angstrom. The crystal grain indicated a main —grain consisting of sub-grains. As the reason that such large crystal grains were obtained, it was considered that due to the effect of the amorphous layer 22, the average crystal grain diameter of the crystal layers 23 and 24 did not be fine to 100 angstrom or less and the large crystals having a grain diameter of five times or more of the layer thickness (20 angstrom) could be formed with good orientation.

[0034]

Further, since such high oriented Cr crystal layer 24 was formed as an under-film, the bi-crystal structure would be formed when the CoPt film was formed. In the conventional magnetic medium of which a thick film having the bi-crystal structure was formed, the thick film was formed by a sputtering method and the like while heating the substrate at 300° C. In the present embodiment, the bi-crystal structure was obtained without such heat-treatment.

[0035]

When measured the unevenness of a surface of the under-film using AFM (Atomic Force Microscope), the maximum Rmax of surface unevenness was 8 angstrom or less which was excellent in its evenness.

[0036]

Next, Figs. 6 and 7 show a sectional TEM photograph of a comparative example of the embodiment and a sketch thereof made by the inventor. In the comparative example, on an alumina 41, an under-film 42, 43 which contains Cr and has not an amorphous layer was formed, and on the under films, a CoPt film 44 was formed. The under-film of Cr was composed of a reactive crystal layer 42 and a crystal layer 43. The Cr crystal layer 43 in the comparative example had an average crystal grain diameter of 100 to 200 angstrom which was thinner than five times of the thickness of the crystal layer 43, and an interface between the CoPt film 44 and the crystal layer 43 had a large unevenness. A plan TEM photograph and a sketch thereof in this comparative example are shown in Figs. 8 and 9, respectively.

[0037]

Further, a crystal grain diameter of the CoPt film 25 was in the range of 100 to 200 angstrom which is small.

[0038]

In addition, from the result of measured electron diffraction pattern, it was found that the crystal orientation of the crystal grains in the comparative example was quite different from that of CoPt film 44 in the present embodiment. Further, the bi-crystal structure of CoPt film could not be obtained. Furthermore, the coercive force Hc of the comparative example was 600 [Oe] which is lower.

[0039]

Next, we will describe magnetic characteristics of the hard magnetic film of the embodiment.

[0040]

The coercive force Hc of the CoPt film 25 was about 2200 Oe or more, and the residual magnetization Mr thereof was about 900 emu/cc or more. Although a film thickness is thin, it shows excellent characteristics.

[0041]

And, as mentioned above, the surface of the hard magnetic film had a bi-crystal structure and the squareness ratio S was a high value of 0.9 or more The high squareness ratio of the hard magnetic film is desirable when the hard magnetic film is used in a state of residual magnetization as a bias film.

[0042]

These excellent properties greatly depend on the combination with the substrate material.

[0043]

Fig. 11 shows combinations of the substrate material and the under-layer metal material, and the relation between the combinations and the coercive force Hc and saturation magnetization Ms of the hard magnetic film. Among them, although as an under-layer metal one material is shown, the reactive amorphous layer of the under-layer metal film contains these metals and a structural element of substrate material. As seen from Fig. 11. with respect to the coercive force, the use of an alumina substrate with Cr or V produce a best property. Next, the uses of a Si having a (100) plane as a surface and T-SiO2 follow. With respect to the saturation magnetization Ms, the uses of the combination of a Si having a

17

(100) plane as a surface and V produces the best property, and next, the combination of

alumina and V, and the combination of T-SiO₂ and Cr or V follow.

[0044]

Next, Fig. 10 shows the relation between the combinations of a magnetic amorphous

layer of CoZrNb, various metal crystal layers and a hard magnetic film of CoPt and the

coercive force Hc of the CoPt hard magnetic film and the saturation magnetization Ms of the

CoPt hard magnetic film. Even if on the amorphous layer of CoZrNb layer, the metal crystal

layer having the same thickness is formed, the under metal layer containing V was slightly

better than the under metal layer containing Cr. As a combination other than the combinations

recited in Fig. 10, a combination of a magnetic amorphous layer such as a CoZrNb layer and

a nonmagnetic crystal layer, and the combination of a nonmagnetic amorphous layer and a

nonmagnetic crystal layer, are given.

[0045]

Fig. 12 recites a thickness of the amorphous layer and crystal grain diameter of Cr.

When the Cr amorphous layer is not formed, magnetic characteristics of CoPt film such as a

coercive force Hc are very poor. On the other hand, when a Cr amorphous layer is formed,

the magnetic characteristics of CoPt film is good.

[0046]

Fig. 13 recites the combinations of main structural elements of under metal film and hard

magnetic films, and the coercive force Hc and a saturation magnetization Ms thereof. These

are examples of which alumina gap films are used as an under layer of all under metal film

All examples show good values, particularly, a $Co_{80}Pt_{20}$ hard magnetic film which uses Cr

and/or V as an under metal is suitable because of both good Hc and Mr .

[0047]

Next, Figs. 14 and 15 depict the thickness- dependency of these magnetic

characteristics. When a thickness of Cr crystal layer is 40 angstrom or more, the coercive

force thereof becomes steady around 2000 Oe, and the saturation magnetization thereof

becomes steady around 850 to 950 emu/cc , and the thickness—dependency disappears.

[0048]

18

Next, we will describe a forming method of the Co base hard magnetic film of the present embodiments by using Fig. 1.

[0049]

First, on an $Al_2O_3.TiC$ substrate (not shown), an alumina layer 21 was formed in a thickness of 1000 angstrom using by sputtering method and the like. After opening a film-forming room, using another sputtering apparatus, a strong electric field of 200 W or more was applied on a surface of the alumina layer 21 to etch by sputtering using an inactive gas such as Ar ion, Kr ion, Xe ion, and He. After them, a Cr layer having a thickness of 50 angstrom was formed by the RF (radio frequency) magnetron sputter method using a Cr target. In this case, without heating the substrate, the excellent characteristics mentioned above could be obtained. But it is more preferable to heat the substrate. After the sputtering, on the surface of alumina substrate, the reactive amorphous layer 22, the reactive crystal layer 23, and the crystal layer 24 were in turn from an alumina surface side. Subsequently, a CoPt film 25 was formed with a thickness of about 220 angstrom by DC (direct Current) magnetron sputter method, thereby the hard magnetic film which uses as a longitudinal bias layer being obtained.

[0050]

After then, a magnetoresistance effect film, and a pair of lead terminals connecting to both edges of the film were formed to complete a thin film magnetic head.

[0051]

Although there are many methods for obtaining an amorphous layer, the most simple method for obtaining the amorphous layer is to sputter with high etching power on a film surface of the under layer such as an alumina layer. The relation between the etching power (W) and the thickness of an amorphous layer is shown in Fig. 16. Although one kind of metal (Cr) is sputtering at a predetermined time (3 min.), by increasing the sputter etching power on the alumina, the thickness of reactive amorphous layer can be controlled, particularly, by increasing the power up to 200W or more, a film having a constant thickness (about 20 angstrom) can be obtained.

[0052]

Fig. 17 is also show the relation between the thickness of amorphous layer and the coercive force Hc of CoPt film 25.

[0053]

Further, Fig. 18 shows the relation between the sputter etching power and the coercive force Hc Oe of CoPt film 25, and Fig. 19 shows the relation between the sputter etching power and Ms emu/cc. When a thickness of the amorphous layer was formed around 20 angstrom (Fig. 16), it was confirmed that the coercive force Hc and the residual magnetization Mr was sufficiently high.

[0054]

Further, Fig. 20 shows the relation between the sputter etching power and the surface roughness Rmax (angstrom) of CoPt film 25. It was confirmed that by controlling the sputter etch power the thickness of amorphous layer could be controlled and the surface roughness of CoPt film could be decreased.

[0055]

Further, Fig. 21 shows the relation between the sputter etching power and the crystal grain diameter of Cr crystal layer 24 and Fig. 22 shows the relation between the sputter etching power and the sub-grain diameter of CoPt film 25. When the sputter etching power is 200 W or more, an amorphous layer is formed. As the result, the crystal grain diameter of Cr crystal layer 24 becomes large, and simultaneously the grain diameter of CoPt film 25 becomes large.

[0056]

Furthermore, as recited in Fig 23, it was confirmed that a CoPt film having a bi-crystal structure was formed.

[0057]

Further, as shown in Fig. 24, in addition to the high coercive force 2200 Oe, the CoPt film 25 had a high squareness ratio of 0.9 or more. Although the CoPt film was a continuous film in which main –grains were not continuous, since by the bi-crystal structure, it could obtain a structure in which sub-gains having a high magnetic isotropy in plane were crossed at right angles to each other, and thus it was difficult to be affected by the magnetization reversal of

20

the adjacent main grains, the high squareness ratio thereof could be obtained. Also, since the Hk of sub-grain is high, when the magnetic sensing layer and the hard magnetic layer were exchange-coupled at the interface, the magnetization direction of the hard magnetic layer did not easily reversed due to the magnetization reversal. This suppresses the occurrence of Barkhausen noise.

[0058]

Next, Fig. 25 shows a relation between an etching power and a thickness of a Cr reactive crystal layer 23. When the etching power is 200 W or more, it is possible to be thin the film thickness of the reactive crystal layer 23.

[0059]

Next, Fig. 26 shows the dependency of an ultimate vacuum (back pressure) of a coercive force Hc (Oe) of CoPt film at the time of sputtering of CoPt film 25. Even when a back pressure at sputtering is low (10^{-6} Torr), a CoPt film 25 having a high coercive force can be stably obtained.

(Second Embodiment)

Fig. 27 is a cross section for explaining the other embodiment of magnetoresistance effect head of the present invention.

[0060]

On a substrate such as an Al_2O_3 .TiC substrate (not shown), a nonmagnetic film such as an alumina film 51 was formed with a film thickness of about 1000 angstrom, further on the nonmagnetic film 51, a CoZrNb amorphous layer 52 having a film thickness of about 20 angstrom, a CoZrNb crystal layer 53 having a film thickness of about 40 angstrom, and a CoPt film 54 having a film thickness of about 220 angstrom were formed. The forming of the CoZrNb amorphous layer was performed by using a CoZrNb target having a Co content of less than 90%, and the forming of the CoZrNb crystal layer was performed by using a CoZrNb target having a Co content of 90% or more These amorphous layer 52 and the crystal layer 53 constitute an under film 55 of a hard magnetic film such as a CoPt film 54. On a surface of the CoPt film 54, a magnetoresistance effect element (not shown) and a pair of

21

lead terminals (not shown) connecting to both edges of the magnetoresistance effect element are formed.

[0061]

An amorphous layer 52 contains as a structural element a structural element in the nonmagnetic film. In the present embodiment, the amorphous layer 52 contains at least one of Al and O which is a structural element of alumina. These Al and/or O react with Cr

[0062]

The hard magnetic film of the present invention was observed by a cross section TEM (Transmission of Electron Micriscope) photograph. As the result, it was found that the under film 55 has a two-layered structure composed of a crystal layer 53 and an amorphous layer 52. Further as a result of observation of the surface of the CoPt film 54 by the plane TEM photograph, an average crystal grain diameter of the CoPt film 54 was in the range of 500 to 1000 angstrom. The reason thereof is considered that due to the effect of the amorphous layer 52, crystal grains of the crystal layer 53 did not form fine crystal grains such as 100 angstrom or less, and formed with much larger diameter and with a good orientation. Owing to such high oriented crystal layer 53, the CoPt film 54 having a bi-crystal structure was obtained

[0063]

Next, we will describe as to the characteristics of the hard magnetic film of the present embodiment.

In spite of a thin film thickness of 60 angstrom, excellent characteristics were shown such that the coercive force Hc of the hard magnetic film was about 2200 Oe, and the residual magnetization Mr is 900 emu/cc.

[0064]

In addition, due to the amorphous layer 52, the dependency of the film thickness of the under layer on the coercive force Hc and the residual magnetization Mr of the CoPt hard magnetic film was decreased. Also, when a thickness of crystal layer 24 was 40 angstrom or more, the dependency of the film thickness of the under layer was practically disappeared, then stable magnetic properties was obtained. The squareness ratio S of the CoPt film was

perhaps 0.9 or more. Such high squareness ratio is preferable when the CoPt hard magnetic film is used as a bias film in a residual magnetization state.

[0065]

Next, we will describe a forming method of the present embodiment using Fig 27.

[0066]

First, on an Al_2O_3. TiC substrate (not shown), an alumina film 51 is formed by a sputter method and the like with a film-thickness of 1000 angstrom, then after opening the film-forming room to an open air, by using other sputtering apparatus a sputter etching is performed on a surface of the alumina film 51 using an inert gas such as Ar ion, Kr ion, Xe ion, He ion and the like. Then, using a CoZrNb target, a CoZrNb amorphous layer was formed by the RF (Radio Frequency) magnetron sputter method. Subsequently, using a target containing above mentioned content % of Co, a crystal layer 53 was formed. Then, a CoPt film 54 was formed with a film thickness of about 20 angstrom by the DC (Direct current) magnetron sputter method, the Co based magnetic hard film of the present embodiment being obtained. Thereafter, a magnetosistance effect film, a pair of lead terminals connecting to both edges of the magnetoresistance effect film, and the like were formed to complete a thin film magnetic head.

(Third embodiment)

Figs. 28 (a) to 28(c) show the cross section of essential parts of an exchange-coupling type magnetoresistance effect head of the third embodiment.

[0067]

In the present embodiment, on a main surface of an Al_2O_3.TiC substrate 60, a shield layer 60' was formed, and on the shield layer an alumina layer 61 was formed. On a partial region of the alumina layer 61, an under metal film composed of a reactive amorphous layer 62 containing Cr and a Cr crystal layer 63, and a hard magnetic film 64 such as a CoPt film were formed. The alumina layer 61, the reactive amorphous layer 62 containing Co, the reactive crystal layer 62', the Cr crystal layer 63, and the CoPt hrad magnetic film 64 were prepared with the same conditions and processes with those of the first embodiment. A

23

magnetoresistance effect film 65, for example, a spin valve film was formed on an open portion holding between a CoPt film 64 and CoPt film 64 and was elongated on the CoPt films, to form an exchange coupling between the CoPt film 64 and a ferromagnetic layer of the magnetoresistance effect film. A pair of lead terminals 66 are formed on both edges of the magnetoresistance effect film 65, and a surface thereof was covered with an insulating protection film 67 .

[0068]

As shown in Fig. 28(b), the spin valve structure is formed of , from a substrate side, a CoZrNb layer having a film thickness of about 100 angstrom, a NiFe layer having a film thickness of about 20 angstrom, a CoFe layer having a film thickness of about 30 angstrom, a Cu layer having a film thickness of about 30 angstrom, a CoFe layer having a film thickness of about 20 angstrom, an IrMn layer having a film thickness of about 80 angstrom, and a Ta layer having a film thickness of about 100 angstrom, in the order A lead wiring 66 has a laminate structure of a Ta layer, a Cu layer and a Ta layer in the order from a side of the magnetoresistance effect film.

[0069]

In the present embodiment, since the hard magnetic film has a high coercive force Hc, it is suitable for lower floating or contact traveling mentioned above. Specifically, in the exchange-coupling system of the present embodiment, the coercive force Hc of the magnetoresistance effect head becomes lower than the coercive force of the hard magnetic film (refer to Fig 39). In this point, the hard magnetic film of the present invention which has a high coercive force Hc is suitable.

[0070]

In conventional hard magnetic film having a low saturation magnetization Ms, due to the exchange coupling with a sensing layer of the magnetoresistance effect film, the total coecive force Hc of a hard magnetic film and a sensible layer was 800 Oe or less, when a film thickness of the hard magnetic film was 200 angstrom. However, the hard magnetic film of the present embodiment has a high coercive force Hc of 2200 Oe and a high saturation magnetization Ms of 900 emu/cc. Even when a film thickness of the hard magnetic film is 200

angstrom, about 1100 Oe can be obtained as a total coercive force Hc where the hard

magnetic film and the sensible layer are in the exchange coupling state.

[0071]

Further, in the present embodiment, a residual magnetization Mr is about 800 emu/cc,

and a squareness ration S is about 0.9 or more. As above, since both are high, the

magnetoresistance effect head of the present embodiment is hardly affected by the magnetic

field of the magnetic recording medium, and thus can obtain a stable and large bias magnetic

field. When an alternating magnetic field of −400 to +400 Oe is applied to the high magnetic

film in the same direction as the magnetic field direction applying from the medium, the

degraded amounts of the residual magnetization Mr of the high magnetic film are shown in

Fig. 29 It is clearly recognized that due to large squareness ratio S, the long time reliability of

the residual magnerization Mr of the high magnetic film is remarkably improved.

[0072]

In the present embodiment, after forming the CoPt film 64, necessary partial regions of

the CoPt film and under-base film were removed by using an ion-milling and the like, and the

magnetoresistance effect film 65 was formed on an opening which exposes a surface of an

alumina 61, and on the CoPT film 64. On a surface of alumina which was exposed by

ion-milling, the surface unevenness of the CoPt film is transferred. However, in the hard

magnetic film of the invention, the surface unevenness is small as mentioned above, and

hence an effect by transferring is small. Therefore, an effect on magnetic characteristics of

the magnetoresistance effect film 65 formed thereon is small.

[0073]

Fig 30 shows a magnetoresistance effect film of the present embodiment and a

comparative example which was formed such that before ion-milling a surface unevenness

(Rmax) was formed on a surface of the CoPt film by sputtering and then by exposing an

alumna layer. With respect to the magnetoresistance effect film having the same structure as

the present embodiment, Fig. 30 shows the relation between the coecive force Hc in a

direction of hard magnetization axis of the sensing layer and an interlayer coupling magnetic

field Hin between a sensing layer and a fixed layer, and the surface roughness (unevenness)

Rmax. It is found that the interlayer coupling magnetic field Hin which affects on the designing a bias point can be enough suppressed to a low level when the surface roughness R max is 10 angstrom or less. This Hc or Hin directly affects on the occurrence of Barkhausen noise, and it is preferable that Hc is 2 Oe or less and the Hin is 10 Oe or less, respectively.

[0074]

Next, the relations between a thickness of a crystal layer, a coercive force Hc in a hard axis direction of the sensing layer and an interlayer coupling magnetic field Hin are shown in Fig. 31. When a thickness is thin, the surface roughness after ion milling can be suppressed. Accordingly, it is found that the Hc and Hin of spin valve film can be suppressed. Thus by improving magnetic characteristics, it is found that the probability of the occurrence of Barkhausen noise becomes smallest when a thickness of the crystal layer is about 60 angstrom which is thin. Further, in an exchange coupling system, when the under metal film is thick, a difference in level at the joining region with the hard magnetic film becomes large, a bias to the magnetic sensible layer is weakened. As the present embodiment, the hard magnetic film with a thin thickness and high saturation magnetization Ms has no necessary to thicken the film thickness for preventing the decrease of coercive force Hc. Accordingly, it is possible to prevent the problem of decreasing of effective bias to the magnetic sensing layer due to the difference in level.

[0075]

The magnetoresistance effect head mentioned above can apply to a recording/reproducing integral type magnetoresistance effect device by constituting the reproducing portion of the thin film magnetic head and by integrally forming a recording portion with the reproducing portion.

(The fourth embodiment)

A magnetoresistance effect head of the present embodiment uses the hard magnetic film which was described in the second embodiment as a hard bias film, and, as shown in fig. 33, is an abutted junction type system in which the hard magnetic film 84 is adjacent to both

edges of the magnetoresistance effect film 86 Further, on the reproducing portion, the recording portion 93 providing a magnetic pole layer 89 which constitutes a low magnetic core, a magnetic gap 90, and a magnetic pole layer 91 which constitutes an upper magnetic core, is integrally formed with the reproducing portion. An effect of the present embodiment is similar to the third embodiment except a peculiar effect by an exchange coupling system.

[0076]

Next, we will describe the peculiar effect of the abut junction type

[0077]

In the present embodiment, due to the high residual magnetization Mr of the hard magnetic film, the hard magnetic film can be allowed to have a thin film thickness necessary to obtain a Mr x t value for applying an enough bias to the magnetic sensible layer. Therefore, it is possible to decrease an excess hard magnetic bias for weakening one way anisotropic magnetic field Hua due to the antiferromagnetic film. Accordingly, there is no problem such as noise increase by that the film thickness of the hard magnetic film is excessively thicken and the film center of the hard magnetic film approaches to the center of the antiferromagnetic film and the magnetic fixed layer.

[0078]

In addition to theses effects, in the junction type of the embodiment, since the film thickness of base metal film is small, a nonmagnetic metal film can be prevented from adhering to edge portions of magnetic sensible layer, Thus, the bias magnetic field can be effectively applied.

[0079]

Further, in the abutted junction system of the present embodiment, in case of a narrow gap length, even if the value of residual magnetization Mr x hard magnetic film thickness t (in the exchange coupling biasing system of the third embodiment, residual magnetization Mr x magnetic sensible layer film thickness t + saturation magnetization Ms of magnetic sensible layer x magnetic sensible layer film thickness t) is the same , the probability of the occurrence of the Barkhausen noise varies corresponding to the residual magnetization Mr. Figs. 34 and 35 show the relations between the probability of the occurrence of the Barkhausen noise and

the film thickness of the under metal crystal layer and the residual magnetization Mr under the condition that the Mr x t = 3.0 memu/cm2, respectively. From Figs. 34 and 35, it is found that by using a hard magnetic film having high residual magnetization Mr, it is possible to more effectively apply a bias compared with the hard magnetic film having a low Mr , thus the Barkhausen noise being greatly decreased.

[0080]

In the above the third and fourth embodiments, a spin valve type GMR film was exemplified as an MR film. However, the present invention can be applied to a multi-layered film of a ferromagnetic film and a non-magnetic film such as Fe/Cr or Co/Cu of which the resistance varies corresponding to the external magnetic field, that is, an MR element using an artificial lattice film. In addition, when an AMR film such as a NiFe alloy (permalloy) having an anisotropic magnetoresistance effect is used, the above-described effects can be obtained.

[0081]

[Effects of the invention]

As mentioned above, the magnetoresistance effect head and the recording/reproducing integrated type magnetoresistance effect element of the present invention can effectively decrease the occurrence of Barkhausen noise by using a hard magnetic film having a high coercive force, saturation magnetization, squareness ratio and the like as a longitudinal bias film or a magnetic domain control film.

[Brief Description of Drawings]

[Fig. 1]

Fig. 1 is a sectional view for explaining the first embodiment of the present invention.

[Fig. 2]

Fig. 2 is a TEM photo showing a section of the first embodiment

[Fig. 3]

Fig. 3 is a sketch of the TEM photo showing a section of the first embodiment.

[Fig. 4]

Fig. 4 is a TEM photo showing a plane of the first embodiment.

[Fig. 5]

Fig. 5 is a sketch of the TEM photo showing a plane of the first embodiment.

[Fig. 6]

Fig. 6 is a TEM photo showing a section of comparative example of the first

embodiment

[Fig. 7]

Fig. 7 is a sketch of the TEM photo showing a section of comparative example of the

first embodiment. .

[Fig. 8]

Fig. 8 is a TEM photo showing a plane of comparative example of the first embodiment

[Fig. 9]

Fig. 9 is a sketch of the TEM photo showing a plane of comparative example of the first

embodiment

[Fig. 10]

Fig. 10 shows the magnetic characteristics of the first embodiment.

[Fig. 11]

Fig. 11 shows the magnetic characteristics of the fist embodiment.

[Fig. 12]

Fig. 12 shows the magnetic characteristics of the first embodiment.

[Fig. 13]

Fig. 13 shows the magnetic characteristics of the first embodiment.

[Fig. 14]

Fig. 14 shows the relation between a thickness of crystal layer of under metal film and a

coercive force Hc of the first embodiment.

[Fig. 15]

Fig 15 shows the relation between a thickness of crystal layer of under metal film and

saturation magnetization Ms of the first embodiment.

[Fig. 16]

Fig. 16 shows the relation between a sputter etching power and a thickness of amorphous layer of the first embodiment.

[Fig. 17]

Fig. 17 shows the relation between a thickness of amorphous layer and a coercive force Hc of the first embodiment.

[Fig. 18]

Fig. 18 shows the relation between a sputter etching power and a coercive force Hc of the first embodiment.

[Fig. 19]

Fig. 19 shows the relation between a sputter etching power and a saturation magnetization Ms of the first embodiment.

[Fig. 20]

Fig. 20 shows the relation between a sputter etching power and a surface roughness of the first embodiment.

[Fig. 21]

Fig. 21 shows the relation between a sputter etching power and a crystal grain diameter of Cr crystal layer of the first embodiment.

[Fig. 22]

Fig. 22 shows the relation between a sputter etching power and a crystal grain diameter of CoPt film of the first embodiment.

[Fig. 23]

Fig. 23 shows the relation between a sputter etching power and a crystal grain diameter having a bi-crystal structure of the first embodiment.

[Fig. 24]

Fig. 24 shows the relation between a sputter etching power and a squareness ratio of the first embodiment.

[Fig. 25]

Fig. 25 shows the relation between a sputter etching power and a reactive crystal layer of the first embodiment.

[Fig. 26]

Fig. 26 shows the relation between a back pressure and a coercive force Hc in the first embodiment.

[Fig. 27]

Fig. 27 shows a sectional view for explaining the second embodiment.

[Fig. 28]

Fig. 28 shows a sectional view for explaining the third embodiment.

[Fig. 29]

Fig. 29 shows the magnetic characteristics of the third embodiment.

[Fig 30]

Fig. 30 shows a coercive force Hc in a hard axis direction of a magnetic sensing layer of a spin valve film and interlayer coupling magnetic field Hin thereof according to the third embodiment.

[Fig. 31]

Fig 31 shows the relation between a thickness of crystal layer and magnetic characteristics of the third embodiment.

[Fig. 32]

Fig. 32 shows the relation between a thickness of crystal layer and Barkhausen noise of the third embodiment.

[Fig. 33]

Fig 33 shows a sectional view for explaining the fourth embodiment.

[Fig. 34]

Fig. 34 shows the relation between a thickness of crystal layer and Barkhausen noise of the fourth embodiment.

[Fig. 35]

Fig. 35 shows the relation between a residual magnetization Mr and Barkhausen noise of the fourth embodiment

[Fig. 36]

Fig. 36 shows a sectional view for explaining a conventional magnetoresistance effect

head

[Fig. 37]

Fig. 37 shows a sectional view foe explaining Barkhausen noise..

[Fig 38]

Fig. 38 shows a graph for explaining characteristics of a hard magnetic film when laminating the hard magnetic film with a magnetic sensing film.

[Description of signs]

4, 21, 41, 61, 85 : nonmagnetic film

5, 24, 44, 64 : hard magnetic film

6, 65, 86 : magnetoresistance effect film

22, 62 : amorphous layer

23 . reactive crystal layer

24, 63 : crystal layer

[Document Name]   Abstract

[Abstract]

[Subject]

The subject is to provide a magnetoresistance effect head and recording/reproducing integral type magnetoresistance effect head which comprise a hard magnetic film having a high coercive force, saturation magnetization, and squareness ration as a longitudinal bias film or magnetic domain control film, and which can suppress the occurrence of Barkhausen noise.

[Means for solving]

The first aspect of the present invention is a magnetoresistance effect head comprising a magnetoresistance effect element formed on a gap layer which is formed on a partial region of a main surface of a substrate, a laminate formed on a surface of the gap layer other than the partial region to hold the magnetoresistance effect element from both sides, the laminate comprising an amorphous layer 22, a metal crystal layer 23, 24 and a hard magnetic film 25

containing Co as a structural element which are formed in the order from side of the gap layer,

and a pair of leads connecting to both edges of the magnetoresistance effect head

[Selected drawing]　Fig. 1 .

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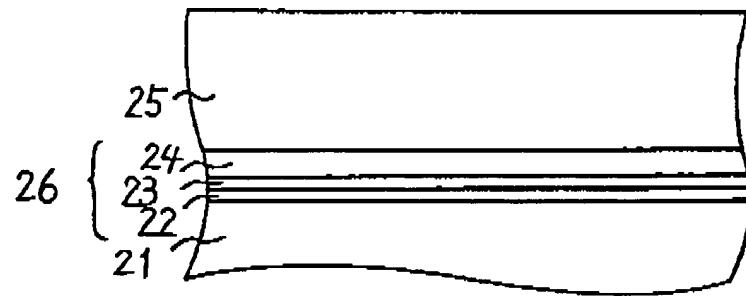
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【 図 1 】

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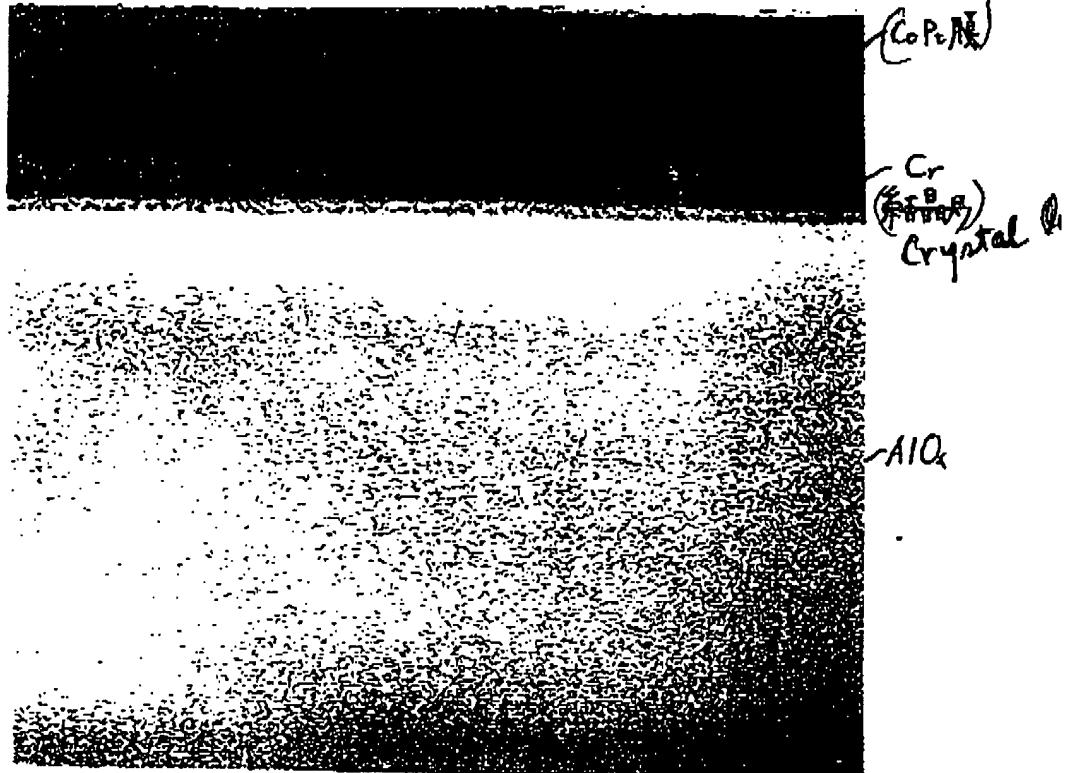
【 書類名 】 図面

整理番号 *13A9670081*

【図　２】

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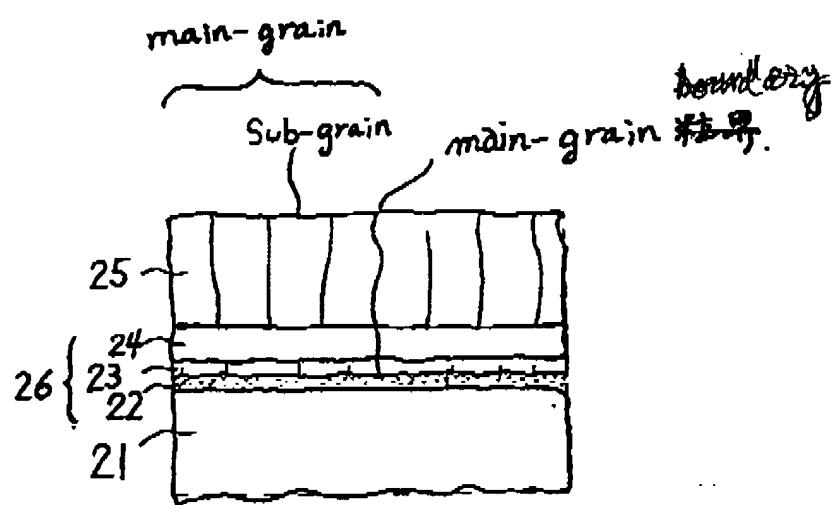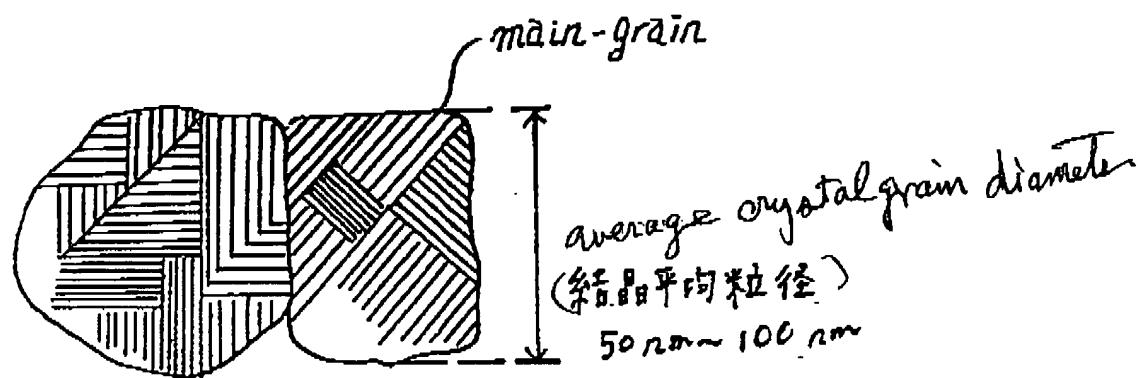
【図3】

整理番号≒

(㈢

4/30

写真

20nm

整理番号 13A9670021

【図 5 】

main-grain

average crystal grain diameter
（結晶平均粒径 ）
50 nm～100 nm

6/30

写真

Surface
(裏面)

CoPt

Cr

反応層 1 (AID)   reactive
(crypto

AlO₂

＝＝ ・100万

整理番号 13A9670081

【図7】

- Hc小
- Hc small

番号 13A9670081

8 】

8/30

写真
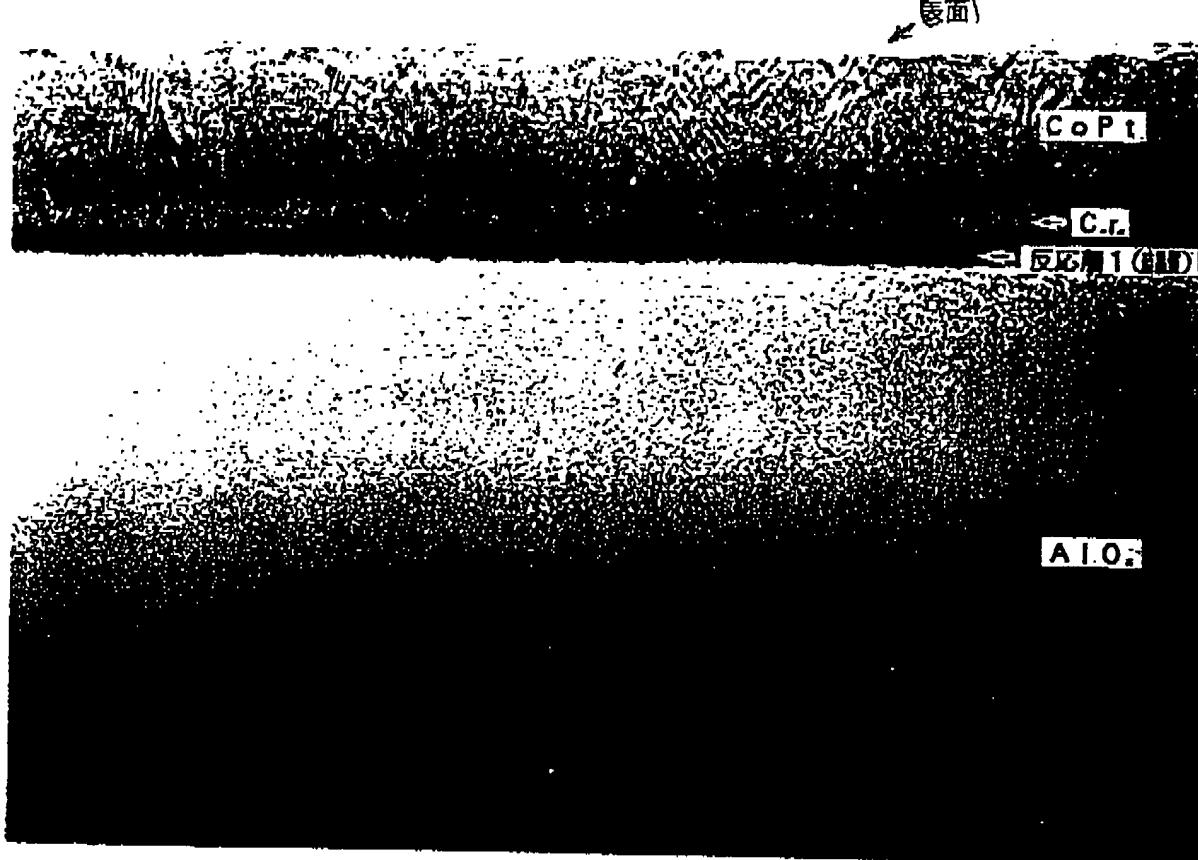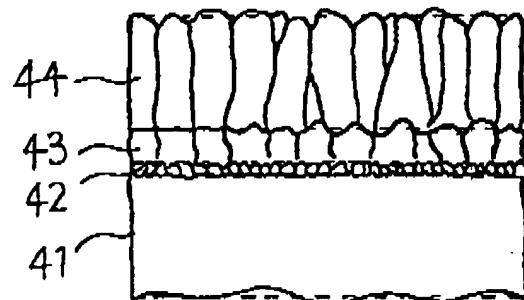
20 nm

整理番号 13A9670031

【図 9 】
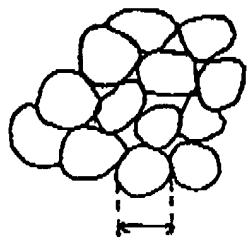
(平均粒径)10 ~ 20 nm

average grain diameter

整理番号 13A9670081

10/3C

【図10】

amorphous layer ↓　　crystal layer　hard magnetic film ↓　　↓

アモルファス層	結晶層	硬磁性膜	Hc 〔Oe〕	Ms 〔emu/cc〕
CZN 20Å	Cr 50Å	CoPt 200Å	1700	700
〃	V 50Å	〃	1700	720
Co Zr-Nb 20Å	Cop1 (Zr-Nb)7	〃	1500	700
Co Zr-Nb 20Å	Cop5 (Zr-Nb)5	〃	1500	720
Co Zr-Nb 20Å	Co Cr	〃	1800	750.

【図11】

Substrate　Base Metal (underlayer metal) ↓　　↓

基　板	下地金属	Hc 〔Oe〕	Ms 〔emu/cc〕
AlOx 1000Å	Cr	2200	900
T- SiO2		1000	820
Si (100)		2000	910
AlOx 1000Å	V	2200	910
T- SiO2		1000	820
Si (100)		2000	920

整理番号 13A9670081

11/3c

【図12】

CrF地アモルファス膜/厚 Thickness of Cr under amorphous layer	結晶配向 Crystal Orientation	Cr 結晶粒径 Cr crystal grain diameter	Cr上に成膜されたCoPt CoPt film formed on a Cr layer
0	bcc	10 ～ 20 nm	X
20	bcc	50 ～ 100 nm	◎

整理番号 13A9670031

【 図13 】

Base metal, hard magnetic film

下地金属	硬磁性膜	Hc [Oe]	Ms [emu/cc]
Cr	$Co_{80}Pt_{20}$	2200	900
	$Co_{75}Cr_{13}Pt_{12}$	2500	720
	$Co_{75}Cr_{13}Ta_{12}$	2500	700
V	$Co_{80}Pt_{20}$	2200	920
	$Co_{75}Cr_{13}Pt_{12}$	2500	740
	$Co_{75}Cr_{13}Ta_{12}$	2500	710
Cr	$Co_{75}Cr_{13}Ta_8Pt_4$	2550	720
V	〃	2560	740
Ti Cr	$Co_{80}Pt_{20}$	2000	850
	$Co_{75}Cr_{13}Pt_{12}$	2200	780
	$Co_{75}Cr_{13}Ta_{12}$	2200	750
	$Co_{75}Cr_{13}Ta_8Pt_4$	2200	750
Cr V	$Co_{80}Pt_{20}$	2200	900
	$Co_{75}Cr_{13}Pt_{12}$	2300	800
	$Co_{75}Cr_{13}Ta_{12}$	2300	780
	$Co_{75}Cr_{13}Ta_8Pt_4$	2400	780
Ti	$Co_{80}Pt_{20}$	1800	720
Ta	〃	1800	720
W	〃	1800	700
Al	〃	2200	780
Zr	〃	2000	720
Nb	〃	1800	700
Hf	〃	1800	700
Mo	〃	1800	700

整理番号 13A9670001
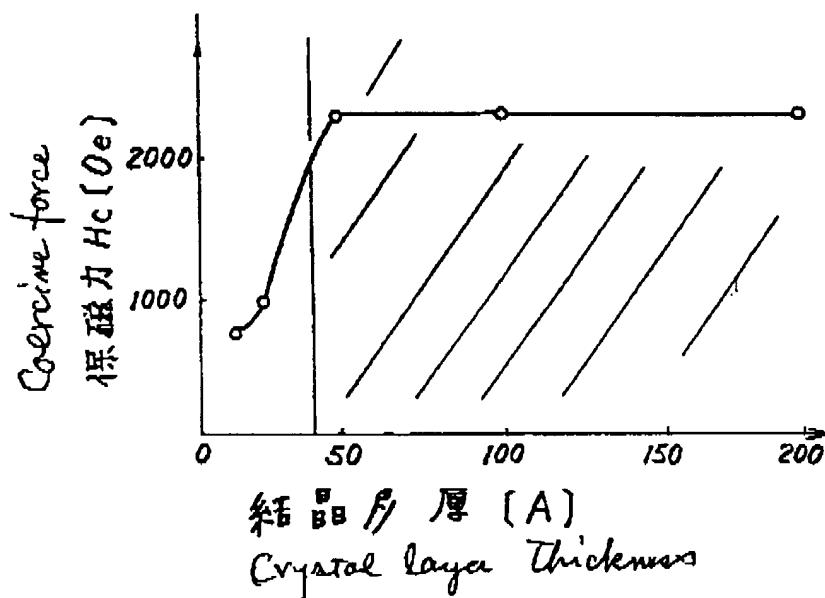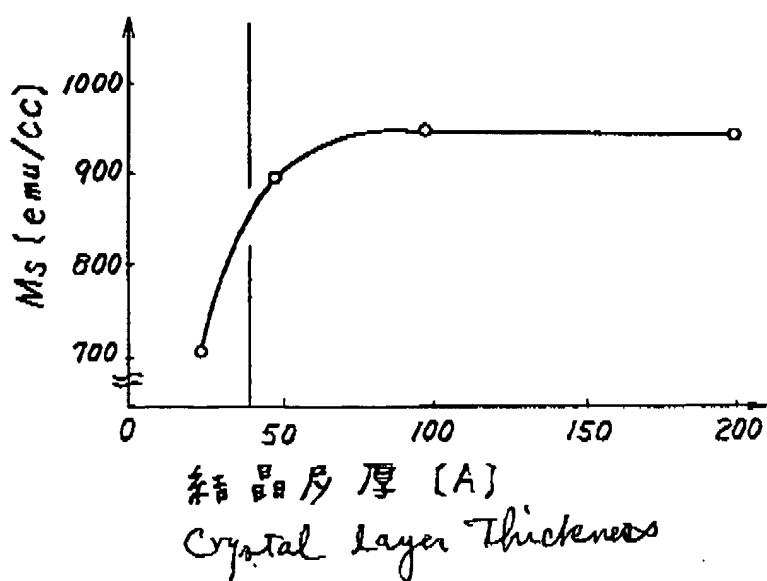
13/3c

【 図14 】

【 図15 】

整理番号 13A96700B1

【図16】

縦軸: Cr under amorphous layer thickness / Cr下地アモルファス層 厚〔Å〕

横軸: スペッタ エッチ パワー 〔W〕
Sputter etching power

【図17】

縦軸: Coercive force / 保磁力〔Oe〕

横軸: アモルファス層 厚〔Å〕
Amorphous layer thickness

整理番号 13A9670031

【 図18 】

【 図19 】

整理番号 13A967008̸1

16/30

【図20】

スパッタ エッチ パワー 〔W〕

Sputter Etching Power
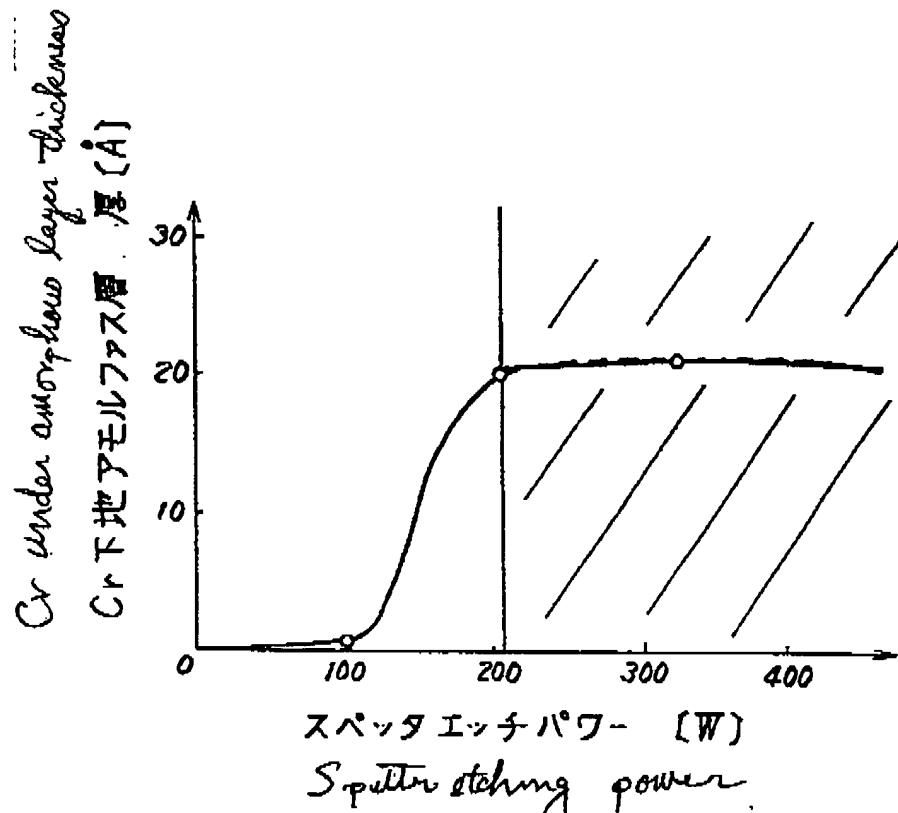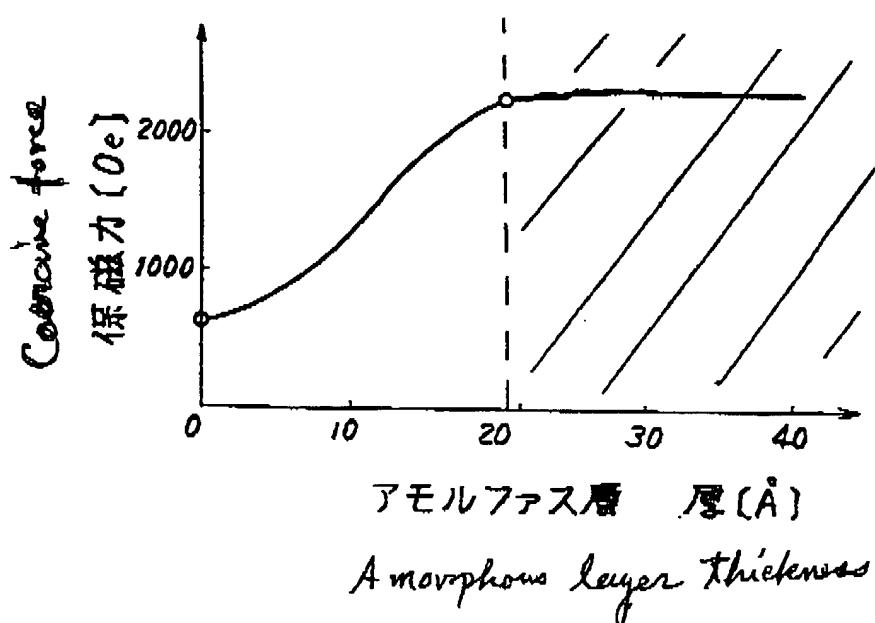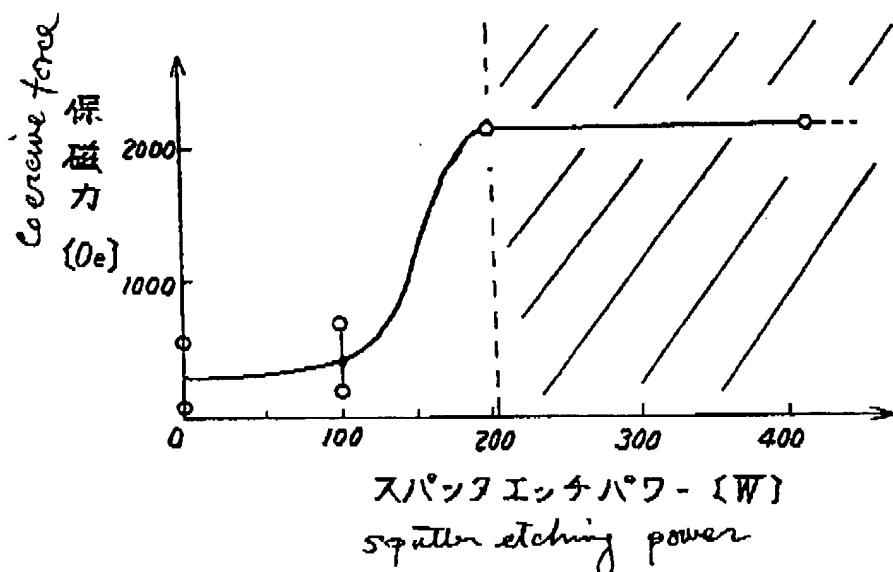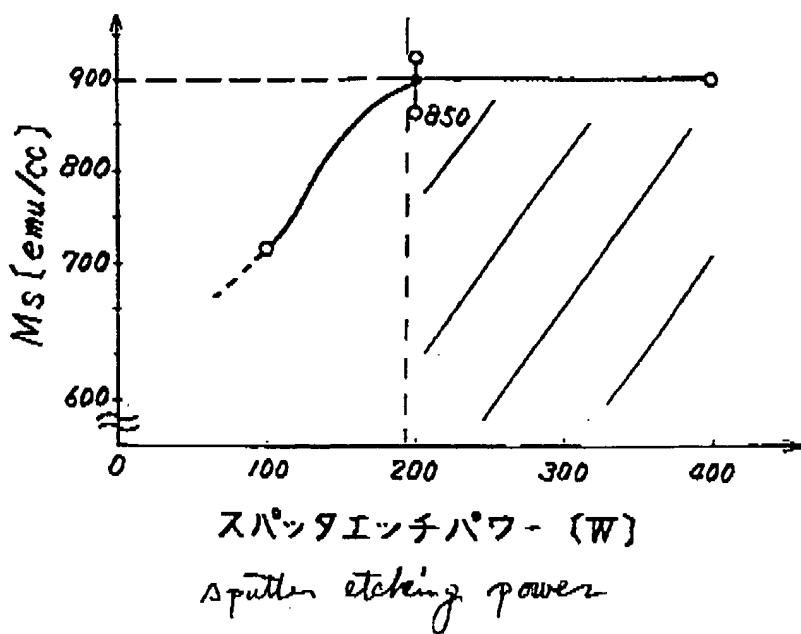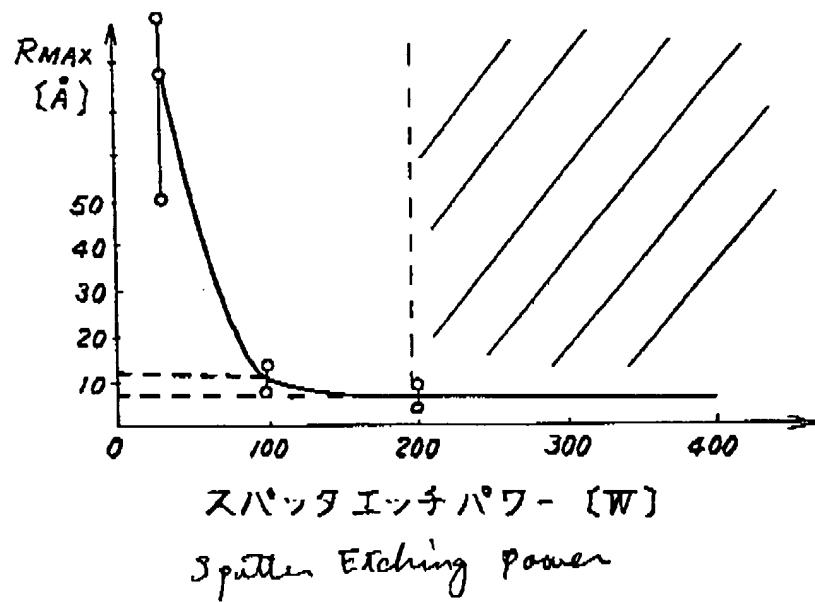
整理番号 13A9670031

77/30

【図21】
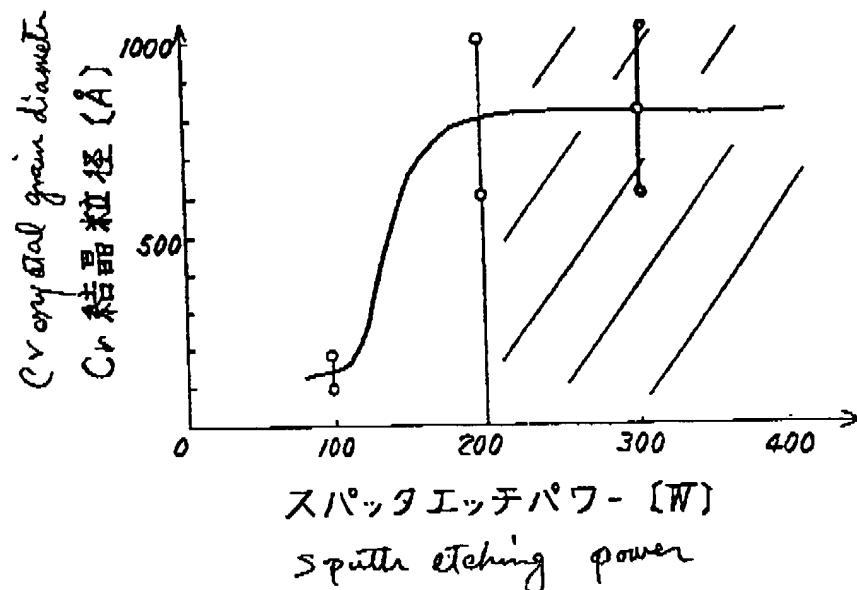
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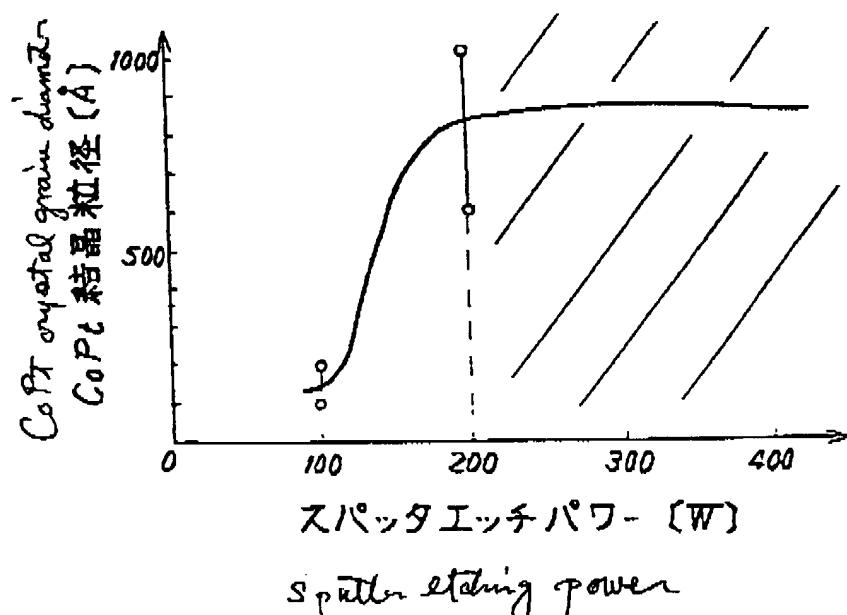
整理番号 13A96700 31

18/30

【図23】
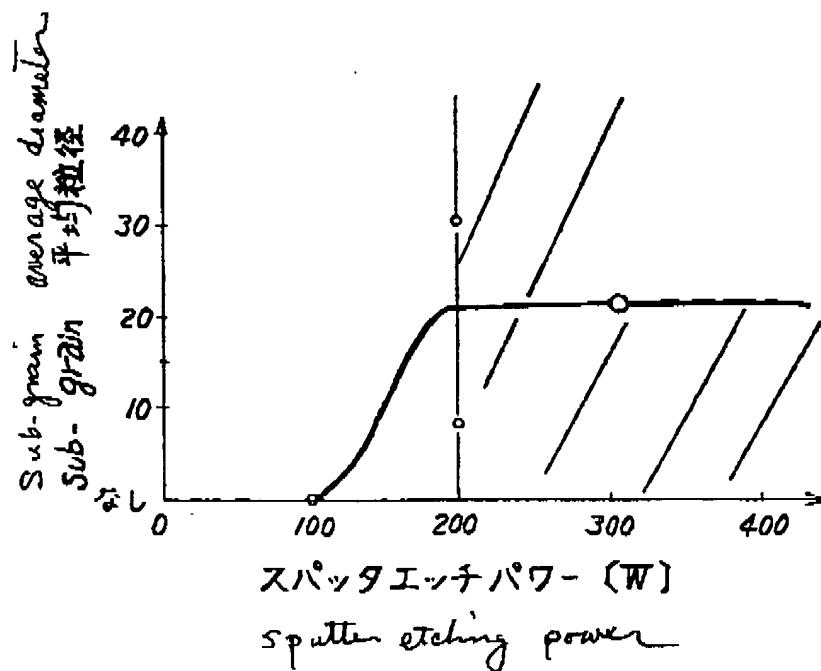
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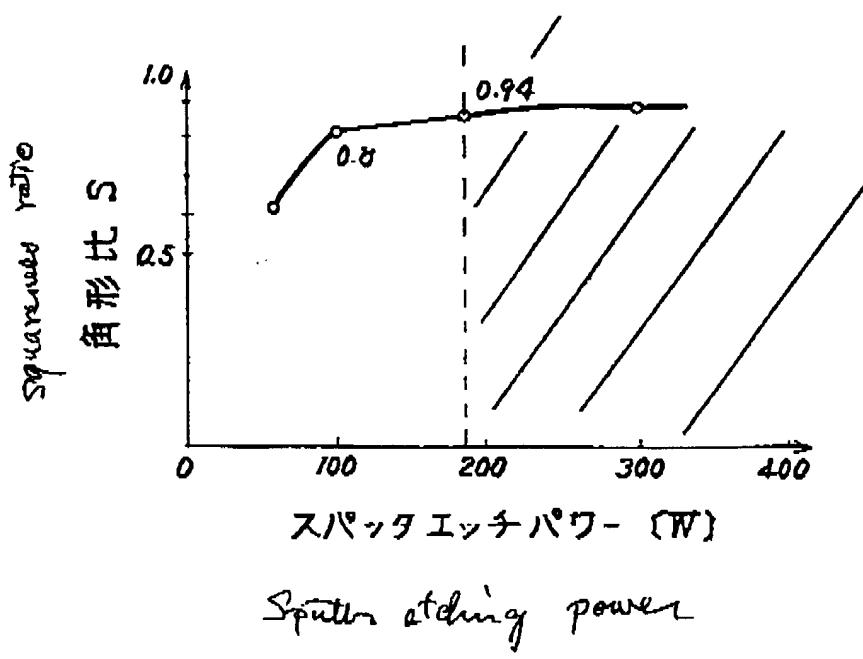
整理番号 13A9670031

19/30

【図25】
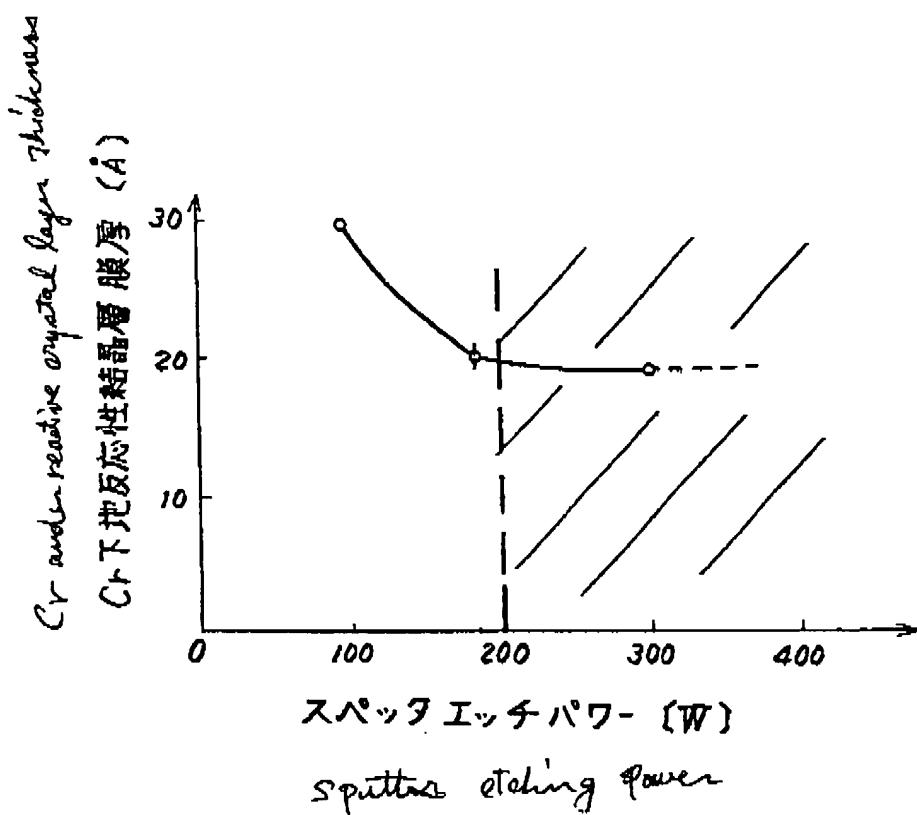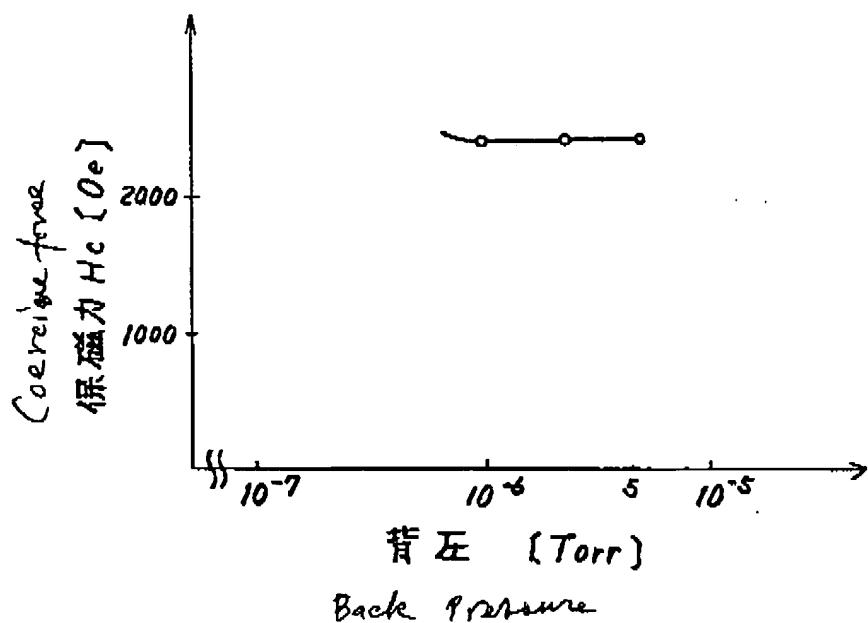
縦軸: Cr under reactive crystal layer thickness / Cr下地反応性結晶層膜厚（Å）

横軸: スペッタ エッチ パワー〔W〕
sputter etching power

整理番号 13A9670031

20/3c

【図26】

背圧 〔Torr〕
Back Pressure

整理番号 13A9670031

【図27】

55

53

52

51

整理番号 /3A9670031

【図28】

(a)

(b) S.V
65
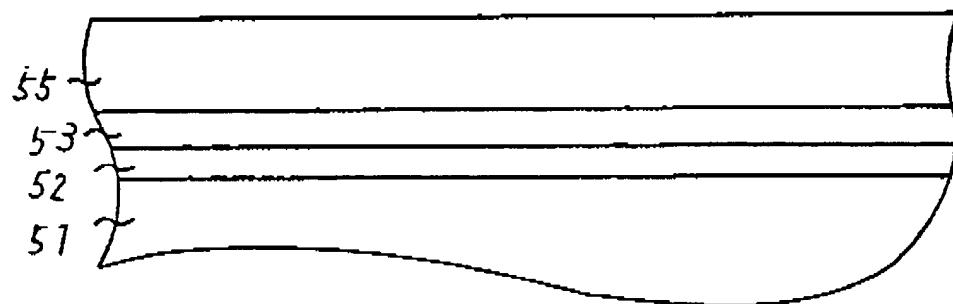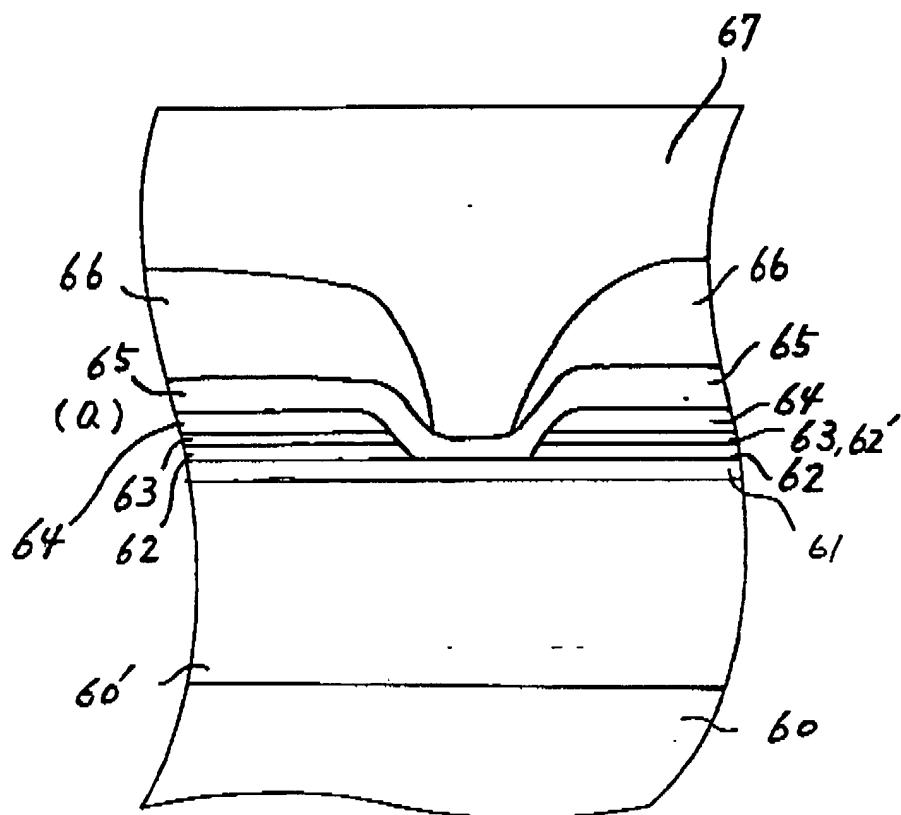
Ta	100Å
IrMn	80Å
CoFe	20Å
Cu	30Å
CoFe	30Å
NiFe	20Å
CoZrNb	100Å

(C) lead (リード)
66

Ta	100Å
Cu	600Å
Ta	100Å

整理番号 13A9670081

23/30

【図29】

(squareness ratio S 0.9)　(squareness ratio S 0.8)

hard magnetic film of present invention　comparative Examples of Figs. 9 and 10

	（角型比S 0.9）本発明の硬磁性膜	（角型比S 0.8）図9. 図10の比較硬磁性膜
着磁後の初期Mr *(Initial Mr after Magnetization)*	800 emu/cc	600 [emu/cc]
交流磁界印加後のMr *(Mr after applying an alternate magnetic field)*	800 emu/cc	520 [emu/cc]

番号 13A 9670031

03

24/30

Before milling,
Surface Roughness of CoPtfilm
Rmax

ミリング前の CoPt膜 表面の 凹凸 Rmax[Å]	Hc	Hin
8	0.1	3.9
80	3	11

整理番号 13A9670031

【図31】

Cr Crystal layer (Thickness) 結晶片 Cr 厚	Hc (Oe) Hard axis direction of Magnetic Sensing layer 感磁層困難軸 方向の Hc 〔Oe〕	Inter layer Coupling magnetic field Hin 層間結合磁場 Hin 〔Oe〕
0 Å	0.1	3.9
200 Å	1.0	

整理番号 13A9670081

【図32】

under Cr crystal layer
of hard magnetic film
(Thickness)

Probability of Occurrence
of BHN

硬磁性膜の 下地Cr 結晶層膜厚	BHN発生確率
0 Å	15 %
60 Å	2 %
200 Å	15 %

整理番号 13A9670031

27/30

【図 33 】
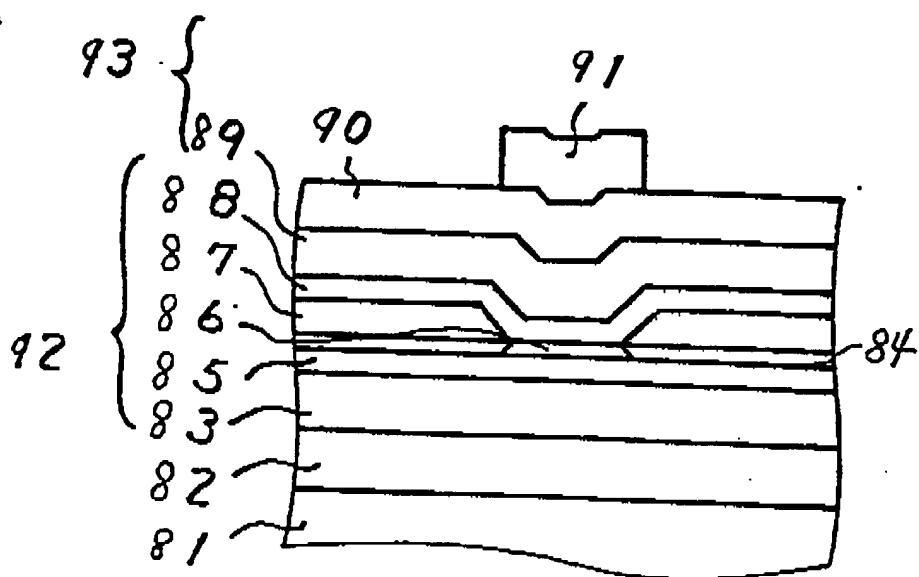
整理番号 13A9670031

28/30

【図34】
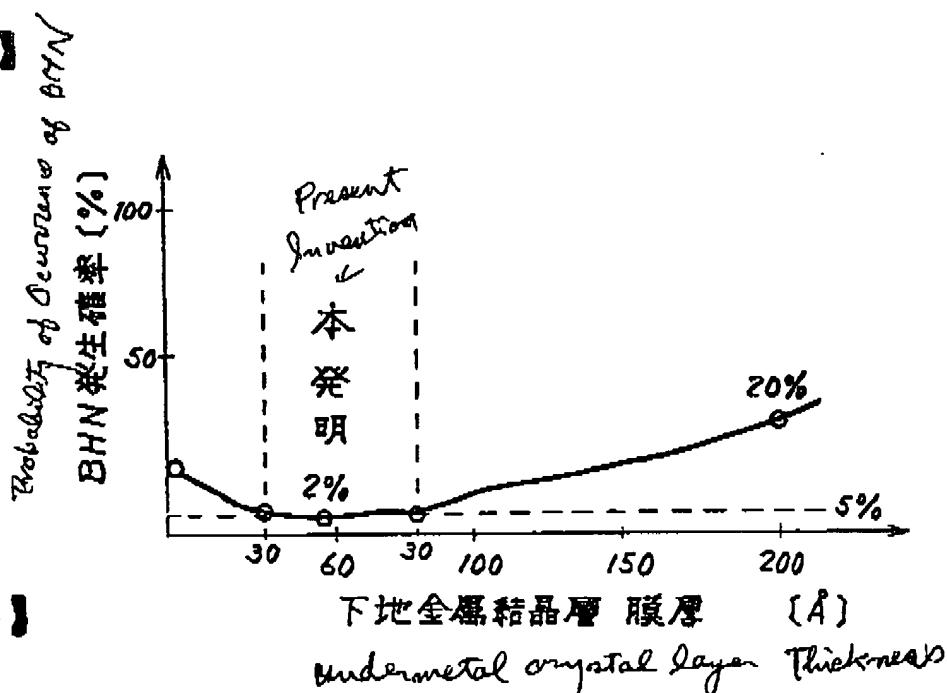
【図35】

整理番号 13A9670031

【図36】

【図37】

整理番号 13A9670031

【図39】

$$\frac{Ms(Hard) \times t(Hard)}{[Ms(Hard) \times t(Hard)] + [Ms(free) + t]}$$